# SCIENTIFIC SATELLITES FOR MONITORING ATMOSPHERIC OZONE

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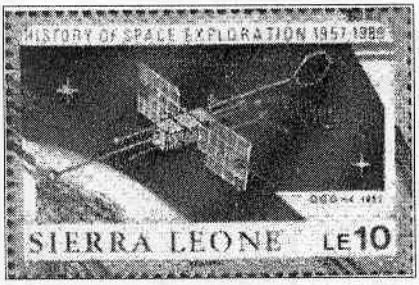
This article has a slightly different theme than previous un-manned satellite articles by the authors. Rather than focusing on a particular satellite series, we instead consider here the measurement of a specific atmospheric constituent, ozone, as carried out by many different un-manned satellites.

Ozone ($O_3$) is a molecule composed of three atoms of oxygen. It exists in minute quantities, mostly in the upper reaches of the atmosphere. Despite these small amounts, ozone is very important for life on Earth: it acts as a shield and prevents certain wavelengths of potentially-harmful ultraviolet radiation from reaching the Earth's surface. In the 1970s, researchers showed that certain man-made chemicals (chlorofluorocarbons, or CFCs) could be transported to high levels in the atmosphere where they would destroy ozone. It was realized in the early 1980s with the discovery of the Antarctic ozone "hole" that this effect was particularly strong over the southern polar area.


Ozone in the atmosphere has been measured from surface-based instruments since the 1920s and from balloon-borne instruments since the 1930s. Such observations, while valuable, are limited in space and time. At the beginning of the modern era of space flight, it became clear that remote sensing from satellites could supply information about the Earth and the atmosphere that would be available in no other fashion. For example, weather satellites were launched to observe the clouds from above. Many other types of measurements of the atmosphere were also done by satellite.

This article follows the history of the measurement of atmospheric ozone by unmanned satellites, from the 1960s through the present, as depicted on stamps and other postal items. Activity related to the Space Shuttle is not included. The Table at the end of the article lists all such postal items known to the authors.

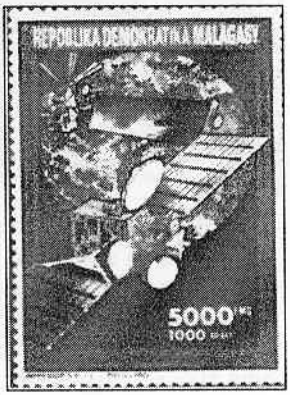

The first known satellite to include ozone-measuring equipment was Ariel-2 (also known




as UK-2), launched in1964. This joint US-British satellite carried one experiment designed to measure the vertical distribution of ozone in the atmosphere, using a photometer and a spectrometer. Ariel-3 carried a similar experiment, but it was for measuring molecular oxygen ($O_2$) rather than ozone. The Ariel series is depicted on many postage stamps. Ariel-2 is found on stamps from Mongolia, Poland and Panama.

The OGO (Orbiting Geophysical Observatory) series included one satellite that studied ozone. It was OGO-4, launched in 1967. A spectrometer that measured backscattered ultraviolet (BUV) radiation was used to determine the vertical distribution of ozone. All the OGOs had similar designs, and many stamps show generic OGOs. Only one, from Sierra Leone, is known to specifically mention and depict OGO-4.

The Nimbus series of weather satellites was discussed by the authors in an article in *The Astrophile* (July/August, 2002 issue). Nimbus-3, launched in 1969, carried an Infrared Interferometer Spectrometer (IRIS) to measure atmospheric temperature, water vapor and ozone. Nimbus-4 (1970 launch) carried a BUV spectrometer for measurements of total amount as well as vertical distribution of ozone. Nimbus-6 (1974 launch) carried another instrument, the Limb Radiance Inversion Radiometer (LRIR), which measured ozone and other atmospheric parameters. Nimbus-7, the last of the series, contained a suite of ozone-measuring instruments: the TOMS (Total Ozone Mapping Spectrometer), the LIMS (Limb Infrared Monitor of the Stratosphere) and the SBUV (Solar Backscatter Ultraviolet Radiometer). It far outlasted its design life: launched late in 1978, it provided data until 1993! It was the first satellite to carry the TOMS, an instrument developed by NASA to measure total column ozone. Many countries have issued stamps or other postal items depicting the generic Nimbus design. In a few of these (see Table 1) Nimbus-3 or Nimbus-4 are referred to or can be identified.




The SME (Solar Mesospheric Explorer) was a science satellite launched in 1981 with several instruments to study ozone amounts, profiles and chemistry in the mesosphere, at levels in the range of 50-80 km. Its main objective was to study how ozone is created and destroyed in the mesosphere and upper stratosphere. It is nicely depicted on one stamp issued by Malagasy / Madagasikara in the year 2000.

UARS (the Upper Air Research Satellite) was launched in 1991 from

Shuttle mission STS-48. It was the first in NASA's Mission to Planet Earth series. Its general goals were to study chemical constituents, solar energy input and chemical and physical processes in the upper atmosphere. It carried several instruments to measure the cycle of ozone creation and destruction and ozone transport in the atmosphere. In particular, the SOLSTICE (Solar Stellar Comparison Experiment) instrument examined how changes in solar energy affect the ozone layer and the ozone hole.


The NOAA series of weather satellites was also discussed by the authors in a recent article in *The Astrophile* (September/October, 2002 issue). NOAA-9, 11, 13, 14, 16 and 17 all carry a Solar Backscatter Ultraviolet Radiometer known as the SBUV/2. This instrument is an updated version of the SBUV that was flown aboard Nimbus-7. It provides ozone profiles and estimates of total column ozone. In addition, NOAA-9 through NOAA-17 are equipped with the TOVS (TIROS Operational Vertical Sounder). Though the main goal of the TOVS is to measure atmospheric temperature and humidity profiles, it also includes a channel that can be used to estimate total column ozone. Only one postage stamp, from the Netherlands, is known to refer specifically to one of these satellites (NOAA-11). The satellite itself is not depicted; rather, a satellite image obtained from this satellite is reproduced on the stamp.


The SPOT (Satellite Pour l'Observation de la Terre) satellites are French environmental-observing satellites. SPOT-3 (launched 1993) carried an instrument known as POAM II (Polar Ozone and Aerosol Measurement II). It was designed to measure the vertical profiles of several atmospheric constituents, including ozone. SPOT-4 (launched 1998) carried the POAM III. While several stamps include generic SPOTs, no stamps are known to depict SPOT-3. The only stamp known to depict SPOT-4 was issued by the French Southern and Antarctic Territory.

ERS-2 (European Remote Sensing Satellite, launched 1995) was the second Earth-observing satellite of the European Space Agency. It carries an instrument known as GOME (Global Ozone Monitoring Experiment) that provides continuous global measurements of total column ozone. Many stamps are known to show ERS-1, but none are known to specifically refer to ERS-2. ERS-1 and ERS-2 have similar designs.

ADEOS-1 (Advanced Earth Observing Satellite) was a Japanese satellite launched in 1996. It unfortunately failed in 1997 after only one year in orbit. It carried a TOMS (Total Ozone Monitoring Spectrometer). Stamps from Japan, Malagasy and Sri Lanka depict ADEOS-1. It appears that ADEOS-2 will not include an ozone-observing instrument.

One recent innovation in space technology is the launching of microsatellites: cheap, light, small satellites that have specific, limited goals. One such satellite was Techsat –1B (Gurwin-2), built by Israel and launched in 1998. One of its instruments was an ultraviolet sensor that measured atmospheric ozone. It failed 10 months into the mission. A special cancel depicting this satellite was used by Israel in 1998.


The latest European environmental-observing satellite is Envisat (launched in 2002). It is hoped that Envisat will provide the most complete set of Earth observations ever made by any satellite. It includes an instrument known as GOMOS (Global Ozone Monitoring by Occultation of the Stars). This instrument will provide ozone profiles over the globe with high accuracy. These data will be used for ozone trend monitoring and understanding of ozone chemistry. Two items are known to depict Envisat: a stamp from Mali and a souvenir sheet from Somalia. However, there is one other stamp issued by the Comoro Islands with an interesting relation to Envisat. This stamp shows the satellite Columbus which was designed but never built. Several of the design elements of Columbus were carried over into Envisat, however.

Ozone-monitoring equipment aboard satellites was first used in the 1960s. As knowledge and space capabilities grew, so did the ozone-monitoring possibilities. The realization in the 1970s and early 1980 that anthropogenic activities were contributing to the destruction of atmospheric ozone provided a strong impetus for more scientific studies of ozone and its chemistry. Ozone data from satellites have been one key element of our understanding of how human activities have been affecting the ozone layer. Images of the Antarctic ozone hole, provided by satellites, have become a symbol of the problem. International cooperation on severely restricting CFCs resulted in a reduced rate of destruction of ozone during the 1990s, and this has in turn led to hope that the ozone layer will recover some time in this new century.

Table 1 lists all the known stamps and postal items that depict ozone-monitoring satellites, or have related content. The authors would be very interested to hear of any other similar items that may have been missed. Images of some of these stamps are included with this article. Others can be found under

the "Ozone-Monitoring Satellites" choice in the Web site developed by the authors: **http://www.cira.colostate.edu/ramm/hillger/satellites.htm.**

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**Table 1 - Checklist of postal items showing Ozone-Monitoring Satellites**

| Country | Cat. No.[1] | Type [2] | Year | Ozone Satellite |
|---|---|---|---|---|
| Central African Rep. | 663 | S/S-1 | 1984 | UARS |
| Comoro Islands | 768 | Stamp & S/S-1 | 1991 | Columbus (pre Envisat) |
| Dominican Republic | 711 | Stamp | 1973 | Nimbus-3 |
| Dominican Republic | C208 | Stamp | 1973 | Nimbus-3 |
| France | | Cancel | 1970 | Nimbus-4 |
| FSAT | C130 | Stamp | 1994 | SPOT-4 |
| Germany | | Meter Cancel | 1969 | Nimbus-3 |
| Israel | | Cancel | 1998 | Techsat-1B |
| Japan | 2134 | Stamp from strip of 2 #2135a | 1992 | ADEOS-1 |
| Malagasy | 1050 | Stamp from S/S-6 & S/S-1 | 1992 | ADEOS-1 |
| Malagasy/ Madagasikara | Unknown | Stamp from S/S-6 | 2000 | SME |
| Mali | 847c | S from S/S-4 #847a-d | 1996 | Envisat |
| Mongolia | C33k | Stamp | 1972 | Ariel-2 |
| Mordovia | Local | Stamp from S/S-6 | 1998? | Nimbus-3 |
| Netherlands | B652 | Stamp | 1990 | NOAA-11 imagery |
| Panama | 472 | Stamp | 1966 | Ariel-2 |
| Panama | 472c (perf & imperf) | S/S-2 (imperf has changed colors) | 1966 | Ariel-2 in margin |
| Panama | 492 | S (o/p of #472 in black or gold) | | Ariel-2 |
| Panama | 492B (perf & imperf) | S/S-2 (o/p of #472c in black or gold; imperfs have changed colors) | 1968 | Ariel-2 in margin |
| Poland | 468 | Stamp | 1966 | Ariel-2 |
| Qatar | 352 | Stamp | 1973 | Nimbus-3 |
| Sierra Leone | 1069i | S from S/S-9 #1069 | 1989 | OGO-4 |
| Somalia | Unknown | S/S-1 | 2002 | Evisat in margin |
| Sri Lanka | 1005 | Stamp | 1991 | ADEOS-1 |
| Zambia | 61 | Stamp | 1970 | Nimbus-3 |

[1]Scott Catalog numbers are used
[2]"S" indicates "Stamp; "S/S" indicates "Souvenir Sheet"